Continental J. Engineering Sciences 9 (1): 9 - 18, 2014
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Printed in Nigeria
ISSN: 2141 – 4068
http://www.wiloludjournal.com
doi:10.5707/cjengsci.2014.9.1.9.18

INFLUENCE OF VARIETY ON OIL YIELD AND OIL RECOVERY OF CASTOR SEED

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ABSTRACT

In this study, oil was mechanically expressed from four varieties of castor seeds using hydraulic press at pressure of 135 kPa and pressing time of 12 minutes, in order to investigate effects of variety and nature of seed on oil yield and oil recovery. Mathematical models were developed by factorial analysis for oil yield and oil recovery. Factors studied were seed variety (white big size (WBS), black big size (BBS), grey medium size (GMS) and grey small size (GSS)) and nature of seed (dehulled seed and undehulled seed). Results of the experiments showed that the two factors significantly influenced oil yield and oil recovery. The model equations predicted 28.69, 21.23, 34.87 and 30.65% oil yield for undehulled WBS, BBS, GMS and GSS respectively; 35.43, 27.98, 41.62 and 37.39% oil yield for dehulled WBS, BBS, GMS and GSS respectively. 52.16, 38.60, 63.40 and 55.72% oil recovery for undehulled WBS, BBS, GMS and GSS respectively; 64.42, 50.87, 75.67 and 67.99% oil recovery for dehulled WBS, BBS, GMS and GSS respectively. The predicted values by the developed models compared favourably well with experimental values.

Key words: Castor seeds, mechanical expression, oil yield, oil recovery, model equations

Received for Publication: 21/01/14 Accepted for Publication: 18/03/14

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INTRODUCTION

Castor plant (*Ricinus communist L.)* is a member of the Euphorbiaceae, which contains a vast number of plants mostly native to the tropics (Akpan, *et al. 2006*). In Nigeria, castor is obtained in every part of the country. Its seed contains 40 to 60 % oil (Olaoye, 2000). The seed is referred to differently depending on the locality where it is found. The Yorubas call it 'Lara', the Hausas refer to it as 'Zurma', and the Kanuris call it 'Kwalakwala', while the Igbos refers to it as Ogilisi (Oluwole, 2010). The oil extracted from the seed is traditionally used as medicinal ointment, illuminant, and as raw material in the soap making industry. At present, the potential of castor oil is not fully explored in Nigeria. Plate 1 shows the four common varieties of the crop that have been identified North Eastern part of Nigeria. These have been named as White Big Size (WBS), Black Big Size (BBS), Grey Medium Size (GMS) and Grey Small Size (GSS) (Oluwole, 2010). Castor seed oil is a colorless to very pale yellow liquid with mild or no odor or taste. The oil is essentially a pure triglyceride and contains almost 90% of glyceryltrianoleate (Marter, 1981). Castor oil is an amber viscous liquid and is sometimes known as ricinus oil (Abitogun *et al.*, *2009*). The oil itself contains a number of fatty acids such as oleic acid, liniteic acid, stearic acid and palmitic acid. Among the vegetable oil however, castor oil is distinguished by its high content of ricinoleic acid that any other vegetable oil (Chakrabarti and Rafiq 2008). Castor oil is unique as it is the only source of an 18-carbon hydroxylated acid with one double bond (Chakrabarti and Rafiq 2008). It has unsaturated bond, high molecular weight, low melting point and very low solidification point which make it industrially useful. Castor oil have applications in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coating, inks, cold resistant, plastics, varnishes, lacquers, oil clothes, linoleum grease, waxes and polishes, nylon, pharmaceuticals and perfumes and also as a raw material in the manufacturing of various chemicals (Oluwole, 2010).

Three major means of recovering oil from oil-bearing biological materials was reported by Olaniyan (2010): wet extraction; solvent extraction and mechanical expression. The wet extraction process is known as hot water or steam extraction method, which is the oldest method of extraction used traditionally by women in rural communities. Alonge and Olaniyan (2003) and Addaquay (2004) used this method for shea butter extraction, Alonge *et al.* (2003) for groundnut oil extraction, Alonge and Olaniyan (2006) for thevetia oil extraction. The same method was used by Oluwole *et al.* (2012) for castor seed oil extraction. The result showed percent of oil expression of 19.42%, which is below the range of the percentage oil content (30 – 55%) of castor seed found in literature (Olaniyan, 2010).

Akpan *et al.* (2006) carried out an investigation on extraction, characterization and modification of castor seed oil using solvent extraction method. Result showed percentage oil extraction of 33.2%. In another development, Shridhar *et al.* (2010) carried out an optimization and characterization of castor seed oil using solvent extraction method. Result showed percentage of oil extraction of 48.75%. Also Abitogun *et al.* (2009) extracted and characterized castor seed oil using solvent extraction method. Result showed that 48% oil was extracted. It was reported by Akpan *et al.* (2006) that the best available method for castor oil extraction at present is by the use of hydraulic press.

Olaniyan (2010) investigated effects of extraction conditions on the yield and quality of oil from castor seed. Result showed maximum oil yield of 41.67% (75.76% oil recovery) at heating temperature of 90 ^{O}C, pressure of 135 kPa and pressing time of 12 minutes using crushed seed. The percentages of oil expressed from castor seed by falls within the range of the percentage oil content (30 – 55%) of castor seed found in literature, depending on the variety.

This study aims at the investigating the influence of variety on castor oil yield and properties from four commonly castor seed varieties found in Borno and Yobe States of Nigeria.

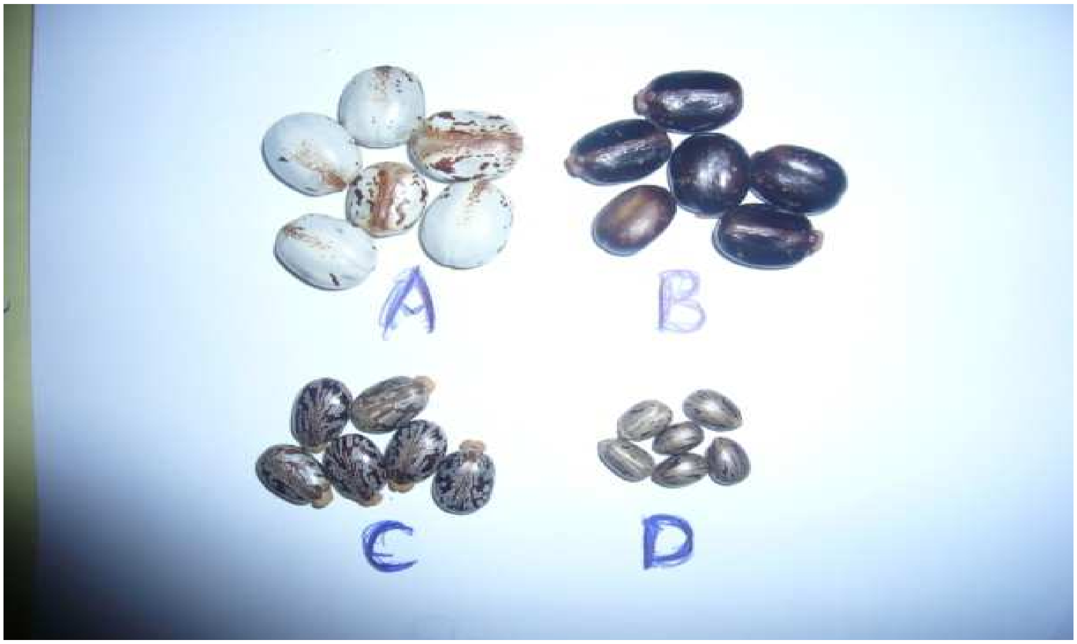

Plate 1.Common Castor seeds: A -WBS; B -BBS; C -GMS; D –GSS
((WBS)-White Big Size, (BBS)-Black Big Size, (GMS)- Grey Medium Size and (GSS)-Grey Small Size)

MATERIALS AND METHODS

Materials Sourcing

Bulk quantities of the four varieties of castor seeds namely; white big size (WBS), black big size (BBS), grey medium size (GMS) and grey small size (GSS) were collected from different localities in Borno and Yobe States of Nigeria. Table 1 shows the varieties of seed as well as the localities from which they were obtained and the uses of which they were made.

Table 1: Castor seeds varieties and locations

S/N	Castor Seed varieties	Location	Local Uses	
			Seed	Plant
1.	White big size (WBS)	Kawuri, Konduga L.G.A. Borno State	Local Condiments (Ogili)	Wind breaker
2.	Black big size (BBS)	Nguru, Nguru L.G.A. Yobe State.	Local Condiments (Ogili)	Wind breaker
3.	Grey medium size (GMS)	Kawuri, Konduga L.G.A. Borno State	Traditional medicine	Wind breaker
4.	Grey small size.	Kawuri, Auno, Konduga L.G.A. Borno State	Traditional medicine	Wind breaker

Moisture Content Determination

Prior to oil extraction, the moisture contents of the seeds were determined using the method reported by ASAE (1983), Aviara *et al.* (2005), Oluwole *et al.* (2007). This method involves oven drying of samples at 130^{O}C for 6 hours.

Oil Expression

The four varieties of castor seeds were prepared for the oil expression by drying the seeds to a moisture content of about 5 to 6% (db), each variety was divided into two (2) to have dehulled and undehulled samples (making a total of eight samples).

One-hundred grams of each sample was expressed for 12 min, using a hydraulic press shown in Plate 2 at pressure of 135 N/m^2. Plate 3 (a) and (b) show expressed oil and cake respectively. The same procedure was repeated for dehulled seed and undehulled seed samples with three replicates making a total of 24 experimental trials that were carried out and the average values were recorded.

Oil yield (ζ_{oil}) was calculated as;

$$\zeta_{oil} = \frac{M_{oil}}{M_{seed}} \times 100\% \qquad (1)$$

Oil recovery was calculated as;$\zeta_{oil\ rec}$

$$\zeta_{oil\ rec.} = \frac{M_{oil}}{XM_{seed}} \times 100\% \zeta_{oil\ rec} = M_{oil}/xM_{seed}\ x\ 100\% \qquad (2)$$

Where $M_{oil} = \text{mass of oil expressed, kg}$

$M_{seed} = \text{mass of oil seed, kg}$

X = oil content of oilseed (0.55 or 55 % from Olaniyan, 2010)

The applied expression force was obtained from the gauge of the hydraulic press and the expression pressure was calculated by dividing the applied force by the cross-sectional area of the press cage cylinder. According to Mu'azu *et al.* (2012), factorial analysis of Design of Experiment is a useful statistical technique which employs multiple regression and correlation analyses as tools to assess the effects of two or more independent factors on the dependent variables. Data obtained from the experiments for measured output (oil yield and oil recovery) were statistically analyzed for analysis of variance (ANOVA) using Design Expert 7.0 software statistical package.

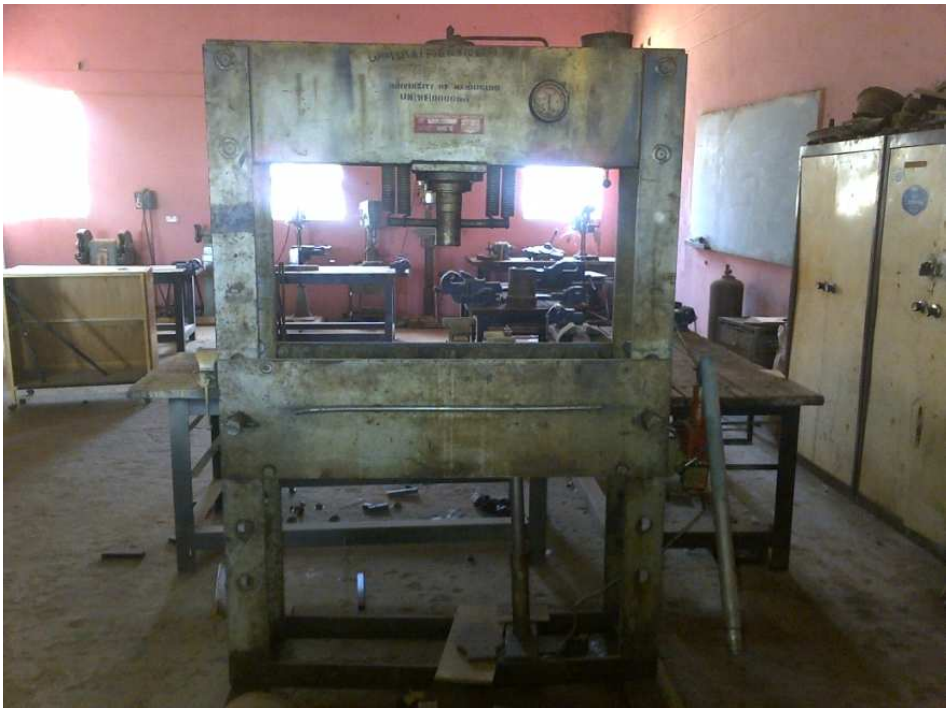

Plate 2: Hydraulic Press used for the oil Expression

(a) (b)

Plate 3: (a) Expressed oil; (b) Cake

RESULTS AND DISCUSSION

Figure 1 shows the oil yield and oil recovery of dehulled and undehulled raw castor seeds. From this figure, it is observed that for each of the four varieties investigated the dehulled seeds gave highest oil yield. This result is similar to the findings of Olaniyan (2010). It is obvious from this figure that the GMS gave the highest oil yield and oil recovery both for dehulled and undehulled seeds, followed by the GSS, then the WBS and the least is observed from the BBS. Generally, the dehulled seeds gave higher oil yield than the undehulled seeds. This may be due to the fact that the chaff of the undehulled seeds must have absorbed some quantity of the oil expressed there by reducing the percent of oil yield.

Figures 2 and 3 show the interactive effects of seed variety and nature of seed on oil yield and oil recovery. It is generally observed from these figures that the dehulled samples gave the highest oil yield/oil recovery compared to the undehulled samples. This is because the chaff of the undehulled seeds absorbed some of the expressed oil.

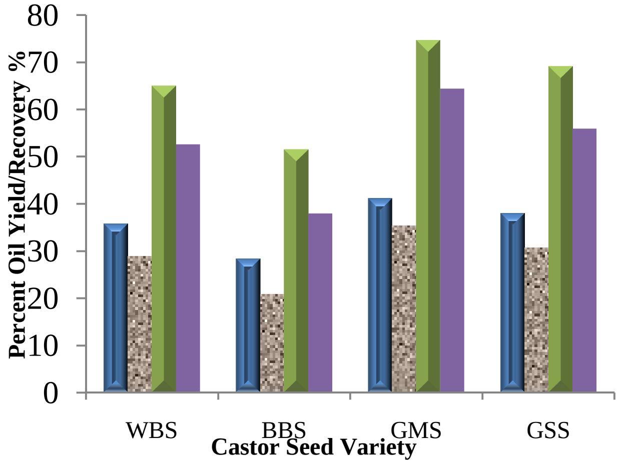

Figure 1: Influence of Variety on Oil Yield of Castor Seed

Table 3 presents the regression coefficient of oil yield model of castor seeds. The negative coefficient term in equation (8) obtained from Table 3 indicates that the WBS and BBS had negative influence, while the positive terms indicate that the GMS and GSS had positive influence on the oil yield. Table 3 show the regression coefficient of oil recovery model of raw castor seeds. The negative coefficient term in equation (9) obtained from Table 3 indicates that the WBS and BBS had negative influence, while the positive terms indicate that the GMS and GSS had positive influence on the oil recovery. In order to validate the model developed, experimental data generated in Tables 3 and 4 (in terms of coded values) were substituted in equations 8 and 9 and the predicted oil yield and oil recovery were obtained as shown in Table 5. The model predicted that the maximum oil yield was 41.62% from dehulled GMS and the minimum was 21.23% from undehulled BBS. It is observed from this Table that the comparison of experimental (actual) values with the predicted values is in close proximity.

Table 3: Regression coefficient of the oil yield of raw seeds

Term	Coefficient Estimate	Df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	32.23	1	0.13	31.96	32.50	
A_1	-0.17	1	0.22	-0.64	0.29	
A_2	-7.63	1	0.22	-8.09	-7.16	
A_3	6.01	1	0.22	5.55	6.48	
B- Nature of seed	3.37	1	0.13	3.10	3.64	1.00

R^2 = 0.9913; (CI – Confidence Interval; VIF – Variance Inflation Factor)

$$O_Y = 32.23 - 0.17A_1 - 7.63A_2 + 6.01A_3 + 3.37B \quad (8)$$

where A stand for the coded value of seed variety
(for WBS, values of $\{A_1, A_2, A_3\} = \{1, 0, 0\}$; for BBS = {0, 1, 0}; for GMS ={0, 0, 1} and for GSS ={-1, -1, -1} and B stand for the coded value of nature of seed)
(for Dehulled seed, value of {B} = {1}; for Undehulled seed, {B} = {-1}

Table 4: Regression coefficient of the oil recovery of raw seeds

Term	Coefficient Estimate	df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	58.60	1	0.23	58.11	59.09	
A_1	-0.31	1	0.40	-1.16	0.53	
A_2	-13.87	1	0.40	-14.71	-13.02	
A_3	10.93	1	0.40	10.09	11.78	
B- Nature of seed	6.13	1	0.23	5.64	6.62	1.00

R^2 = 0.9913 ; (CI – Confidence Interval; VIF – Variance Inflation Factor)

$$O_R = 58.60-0.31A_1-13.87A_2+10.93A_3+6.13B \quad (9)$$

where A stand for the coded value of seed variety
(for WBS, values of $\{A_1, A_2, A_3\} = \{1, 0, 0\}$; for BBS = {0, 1, 0}; for GMS ={0, 0, 1} and for GSS ={-1, -1, -1} and B stand for the coded value of nature of seed)
(for Dehulled seed, value of {B} = {1}; for Undehulled seed, {B} = {-1}

O_Y =oil yield of seed

O_R = oil recovery of seed

Table 5: Factorial design of the oil yield for raw seeds using coded factors in three replicates

	Seed Variety		Nature of Seed		Oil Yield (%)			
					Oil Yield (%)		Oil Recovery (%)	
S/No.	Actual	Coded	Actual	Coded	Actual Value	Predicted Value	Actual Value	Predicted Value
1	WBS	{1, 0, 0}	Undehulled	{-1}	27.93	28.69	50.78	52.16
2	WBS	{1, 0, 0}	Undehulled	{-1}	29.29	28.69	53.25	52.16
3	WBS	{1, 0, 0}	Undehulled	{-1}	27.85	28.69	50.64	52.16
4	BBS	{0, 1, 0}	Undehulled	{-1}	20.98	21.23	38.15	38.60
5	BBS	{0, 1, 0}	Undehulled	{-1}	21.08	21.23	38.33	38.60
6	BBS	{0, 1, 0}	Undehulled	{-1}	20.61	21.23	37.47	38.60
7	GMS	{0, 0, 1}	Undehulled	{-1}	35.33	34.87	64.24	63.40
8	GMS	{0, 0, 1}	Undehulled	{-1}	35.39	34.87	64.35	63.40
9	GMS	{0, 0, 1}	Undehulled	{-1}	35.56	34.87	64.65	63.40
10	GSS	{-1,-1,-1}	Undehulled	{-1}	31.01	30.65	56.38	55.72
11	GSS	{-1,-1,-1}	Undehulled	{-1}	30.67	30.65	55.76	55.72
12	GSS	{-1,-1,-1}	Undehulled	{-1}	30.61	30.65	55.65	55.72
13	WBS	{1, 0, 0}	Dehulled	{1}	36.01	35.43	65.47	64.42
14	WBS	{1, 0, 0}	Dehulled	{1}	35.66	35.43	64.84	64.42
15	WBS	{1, 0, 0}	Dehulled	{1}	35.61	35.43	64.75	64.42
16	BBS	{0, 1, 0}	Dehulled	{1}	28.16	27.98	51.20	50.87
17	BBS	{0, 1, 0}	Dehulled	{1}	28.23	27.98	51.33	50.87
18	BBS	{0, 1, 0}	Dehulled	{1}	28.56	27.98	51.93	50.87
19	GMS	{0, 0, 1}	Dehulled	{1}	40.99	41.62	74.53	75.67
20	GMS	{0, 0, 1}	Dehulled	{1}	41.13	41.62	74.78	75.67
21	GMS	{0, 0, 1}	Dehulled	{1}	41.06	41.62	74.65	75.67
22	GSS	{-1,-1,-1}	Dehulled	{1}	38.27	37.39	69.58	67.99
23	GSS	{-1,-1,-1}	Dehulled	{1}	37.48	37.39	68.15	67.99
24	GSS	{-1,-1,-1}	Dehulled	{1}	36.08	37.39	65.6	67.99

WBS-White Big Size; BBB-Black Big Size; GMS-Grey Medium Size; GSS-Grey Small Size

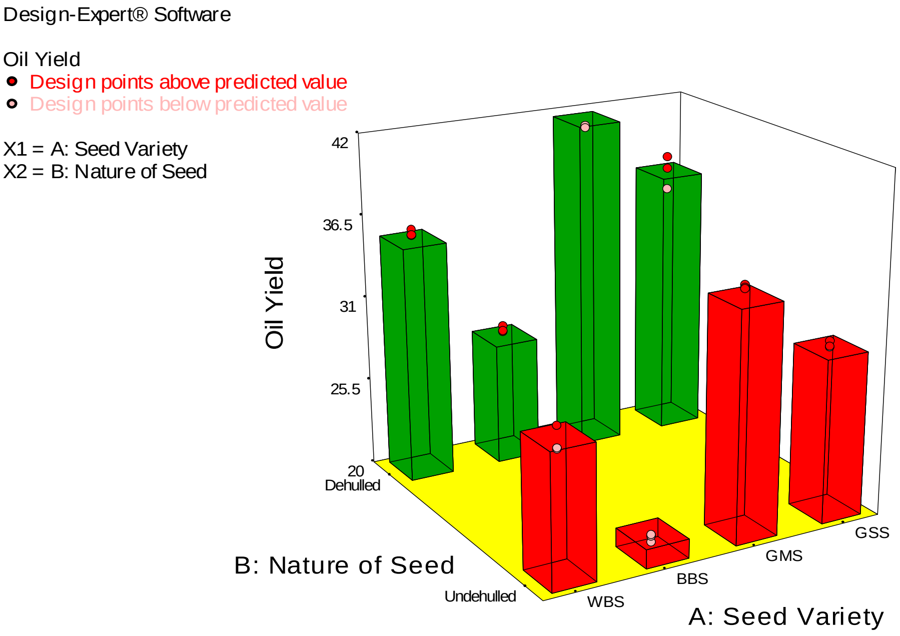

Figure 2: Effects of seed variety and nature of seed on oil yield of castor seeds

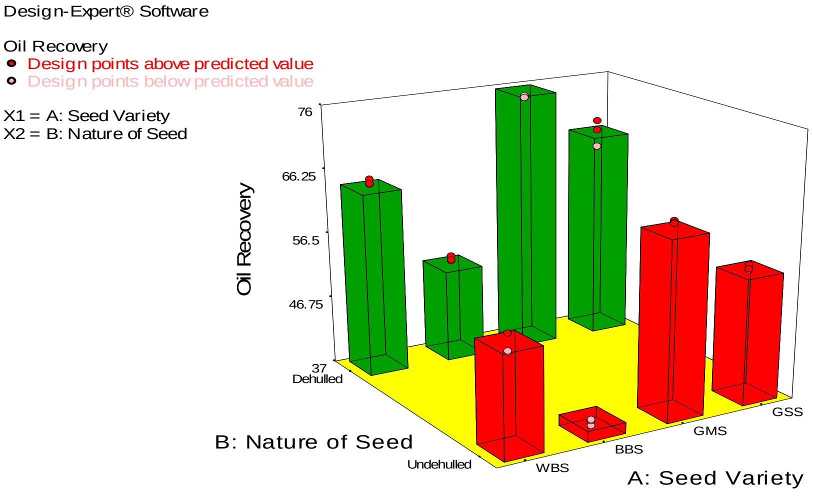

Figure 3: Effects of seed variety and nature of seed on oil recovery of castor seeds

CONCLUSION

In this study, oil was mechanically expressed from four varieties of castor seeds using hydraulic press in order to investigate varietal effect on the seed oil yield and oil recovery. Two factors viz: seed variety and nature of seed were studied. The conclusion derived from this study is as follows:

1. The oil yield/oil recovery of the four castor seed varieties significantly differ at 5% level.
2. The maximum oil yield and oil recovery were observed from the GMS, followed by the GSS, then the WBS and the minimum from the BBS.
3. Generally, dehulled seeds gave higher oil yield/recovery than the undehulled seeds; this may be due to the fact that the chaff of the undehulled seeds must have absorbed some quantity of the oil expressed there by reducing the percent of oil yield.
4. The results obtained from the statistical analysis indicated that the experimental (actual) values are closed when compared with the predicted values for both oil yield and oil recovery.
5. The developed mathematical model can be used to predict the oil yield and oil recovery of castor seeds.

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